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Does Price Uncertainty Really Reduce Private Investment?

A Small Model Applied to Chile

Anita George
and
Jacques Morisset

Uncertainty about the cost of capital should be compared with uncertainty about the price of output. The efficiency of policies to reduce the price of capital may be enhanced if the volatility of the output price is greater than the volatility of the price of capital, and if there is a positive correlation between changes in prices for output and capital.

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This paper a product of the Country Operations Division, Country Department IV, Latin America and the Caribbean — is part of a larger effort in the department to understand private investment in developing countries. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Diane Bievenour, room I6-011, extension 37899 (March 1993, 13 pages).

Understanding how prices and quantities affect investment demand is important in analyzing adjustment policies in many developing countries.

Recent literature emphasizes that uncertainty curtails private investment, adding a risk premium — the price of waiting. Several recent empirical studies have confirmed this result.

This new development has been used to challenge one of the most popular policy recommendations derived from the traditional literature on investment: increasing investment by reducing the cost of capital through tax incentives or exchange rate policies. Because such policies are likely to increase uncertainty about the price of capital, their effect on private investment is ambiguous. The popular intuition is that private investors care more about the uncertainty of the price of capital than its level. In other words, incentives would have to be unreasonably high to bolster investments.

George and Morisset argue that uncertainty about the cost of capital should be compared with uncertainty about the price of output. Using a simple analytical model, they conclude that the efficiency of policies aimed at reducing the price of capital may be enhanced if:

- The volatility of the output price is greater than the volatility of the price of capital.

- And there is a positive correlation between changes in prices for output and capital.

In both cases, private investment will be more responsive to changes in the price of capital (or in aggregate demand) because firms will minimize profit fluctuations.

They apply this model to Chile for 1980-90. Chile is the reputed "success story" of structural adjustment and has achieved fairly stable growth in the past eight years. (The results correspond to the predictions of the analytical model.)

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DOES PRICE UNCERTAINTY REALLY REDUCE PRIVATE INVESTMENT? A SMALL MODEL APPLIED TO CHILE [1/]

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and
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1/ The findings are the authors' own and they should not be attributed to the World Bank.

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Summary

1. Understanding the roles of prices and quantities in investment demand is important for the analysis of adjustment policies in many developing countries. The recent literature emphasizes the negative impact of uncertainty on private investment as a result of a higher risk premium -- the price to wait. Recently, this result has been confirmed by several recent empirical studies.

2. This new development has been used to challenge one of the most popular policy recommendations derived from the traditional literature on investment: increasing investment by reducing the cost of capital through tax incentives or exchange rate policies. Because such policies are likely to increase the uncertainty concerning the price of capital, their effect on private investment is rather ambiguous. The intuitive idea is that private investors care more about the uncertainty concerning the price of capital than its level. In other words, incentives would have to be unreasonably high to bolster investors.

3. This paper argues that the uncertainty concerning the cost of capital should be compared with uncertainty in the price of output. Using a simple analytical model, we conclude that the efficiency of policies aimed to reduce the price of capital may be enhanced (i) if the volatility of the output price is greater than the volatility of the cost of capital, and (ii) there is a positive correlation between changes in the output and capital prices. In both cases, private investment will be more responsive to changes in the price of capital (or in aggregate demand) because firms will minimize profit fluctuations.

4. In the second part of the paper, the model is applied to the case of Chile over the 1980-90 period. This country has earned the reputation of being the "success" story of structural adjustment and has achieved fairly stable growth in the past eight years.

Introduction

One of the established facts in macroeconomics is that business fixed investment and output move strongly together over the business cycle. This relationship might appear to suggest that business fixed investment can be best explained by an accelerator model of investment, whereby investment responds to changes in the desired capital stock, itself determined by the demand for output. In parallel, traditional theory of perfect competition market has suggested that if output prices exceed long run average cost, this induces existing firms to expand, and new ones to enter. Observers of business practice find however that prices should exceed costs by a substantial margin in order to bolster new investment projects. As argued in many recent papers (see Dixit [1992] for a good summary), this difference between the expected revenues of the investment project and the cost reflects the value of waiting. In an uncertain world, information has a price and an investors by reporting their decision will acquire more information, thereby reducing the risk of the investment.

The objective in this paper is to examine the relationships between changes in aggregate demand and uncertainty associated with output and capital prices. Our view in this paper is to claim that, although the cost of capital matters, the volatility of the price of capital and the output price are more important in determining investment. Specifically, using a simple model in which investors act in a risk-averse manner, we demonstrate that in a volatile environment, the impact of a change in output or in the cost of capital on private investment are significantly reduced. This confirms the result obtained in previous studies that uncertainty may outweigh the beneficial effects of reforms on private investment (see Rodrik (1991) or Serven and Solimano (1992)).

Unlike previous studies, the model distinguishes the risk associated with the fluctuations of the price of capital and with the fluctuations of price of output. If uncertainty of the price of capital is greater than uncertainty of the change in output price, then other things being equal, the optimal choice will contain less movement in investment than in GDP. From a policy perspective, economists often recommend increasing investment by reducing the cost of capital through tax incentives. In order to increase the efficiency of such policies, the first priority of the Government should be to reduce the price of capital,

which will increase its volatility in the short-run, when the volatility of the output price is simultaneously high. This can occur during a sharp disinflation. The model also shows that a strong positive correlation between the output and capital prices would enhance private investment because the profitability fluctuations would be minimized. These results are tested empirically in the case of Chile (1970-90).

The paper proceeds as follows. In **Section 1**, we present a simple model in which the private investment behavior is derived. We use a maximizing-profit approach to emphasize that different sources of uncertainty may have opposite implications on private investment. In **Section 2**, we apply the model to the Chilean case. Finally, **Section 3** contains our conclusions and policy recommendations.

1. A Simple Analytical Model

The recent literature on investment has emphasized the irreversibility of investment. Along these lines, sophisticated models in which the decision to invest involves exercising an option -the option to wait for new information- have been developed[2/]. While this theoretical approach appears successful in explaining the opportunity cost of investment in an uncertain context, it can be criticized on two points. First, it might be too radical in assuming that private investors will always react negatively to an increase in uncertainty. One decade ago, some authors (see Abel (1983) or Hartman (1972)) argued that an increase in output price volatility, in contrast to a change in capital price volatility, may enhance private investment. Second, this approach does not take into account the eventual linkages between different sources of uncertainty. Therefore, an alternative model is proposed in this paper.[3/] We will demonstrate that private investment is more sensitive to variations in the price of capital or in aggregate demand if: (i) the volatility of the price of capital is low, (ii) the changes in the output and capital prices are positively correlated, (iii) the firms are less risk averse, and (iv) the volatility of the output price is higher than the volatility of the capital price.

2/ See for example Pindyck (1991) or Dixit (1992).

3/ This approach is based on Greenwald and Stiglitz (1989). In a different context, these authors attempt to explain wage and employment adjustments in an uncertain world.

Firms are assumed to maximize the expected utility of profits (π), where profits are a random function of changes in capital accumulation (K - K*) and changes in output (Y - Y*) . As we are interested in the investment behavior, we assume that changes in the stock of capital are endogenous and changes in output are exogenous.[4/] In other words, firms will adjust their stock of capital according to their expected level of production. To capture the idea that the greater the change in the decision variable and in the exogenous factors, the greater the uncertainty, we write:

$$(1) \qquad \pi_t = \pi(Y^*, K^*, \tilde{p}_k(K - K^*), \tilde{p}(Y - Y^*))$$

where Y*, K* are preexisting levels of output and capital respectively, and $\tilde{p}_k$ and $\tilde{p}$ are random price of capital and output price. Uncertainty associated with changes in output and in the stock of capital are exclusively captured by the uncertainty of prices.

Next, assuming that (K - K*) and (Y - Y*) are relatively small, we linearize the profit function around K* and Y* so that :

$$(2) \qquad \pi_t = \pi(Y^*, K^*) + \pi_1\tilde{p}_k(K - K^*) + \pi_2\tilde{p}(Y - Y^*)$$

where π_1 is the derivative of π with respect to $\tilde{p}_k(K - K^*)$ and π_2 is the derivative of π with respect to $\tilde{p}(Y - Y^*)$. Since an increase in the stock of capital and in production exert a negative and positive impact on the level of profit, π_1 and π_2 are negative and positive respectively.

Finally, we assume a quadratic utility function. Accordingly the firms' objective function can be rewritten in terms of the mean and variance of π where:

$$(3) \qquad E(\pi_t) = \pi_s + \pi_1\bar{p}_k(K - K^*) + \pi_2\bar{p}(Y - Y^*)$$

and,

$$(4) \qquad \sigma^2(\pi_t) = \pi_1^2\sigma^2_{pk}(K - K^*)^2 + \pi_2^2\sigma^2_p(Y - Y^*)^2 + 2\pi_1\pi_2C_{pk,p}(K - K^*)(Y - Y^*)$$

4/ The model can be extended to other exogenous shocks such as variations in credit or in exchange rates.

with p_k and p being the means, σ^2_{pk} and σ^2_p being the variances, and $C_{pk,p}$ being the covariance of p_k and p.

Efficient combinations of (K - K*), the decision variable, are those that minimize $\sigma^2(\pi)$, subject to $E(\pi) > \pi_0$. Solving this problem we get the following investment function:

$$(5) \qquad I_p = (K - K^*) = \alpha[\bar{p}_k/\sigma^2_{pk}] + \beta[(C_{pk,p}(Y - Y^*))/\sigma^2_{pk})$$

$$\text{with } \alpha = [\mu/2\pi_1] < 0 \text{ and } \beta = [-\pi_1\pi_2/\pi^2_1] > 0$$

where I_p is the change in the stock of capital, and μ is the Lagrange multiplier associated with the expected profit constraint (see below for a discussion).

At first sight, the investment function (5) has the conventional properties derived from the neoclassical theory: the lower the expected price of capital or the higher the increase in GDP, the greater is the capital accumulation. But, equation (5) also presents three important characteristics.

First, an increase in the volatility of the price of capital is likely to reduce private investment ($dI_p/d\sigma^2_{pk} < 0$). This result is quite obvious and reflects the fact that the cost to delay an investment project is reduced when the risk of this project is high. In addition, equation (5) demonstrates the higher the uncertainty on the price of capital (σ^2_{pk}), the lower is the impact of a change in the price of capital or in economic growth on investment. Intuitively, if the risk concerning the price of capital variations is high, the response of investment to change in economic growth or interest rates is low because investors tend to prefer the status quo. From a policy perspective, if uncertainty is high, incentives would have to be prohibitively large to have a significant effect on investment.

Second, an increase in the covariance between the output price and the capital price would positively affect private investment. In order to better understand this relationship, we rewrite the covariance as follows :

$$(6) \qquad C_{p,pk}/\sigma^2 p_k = \tau_{p,pk}(\sigma_p/\sigma_{pk})$$

where $\tau_{p,pk}$ denotes the correlation between the output and capital prices, σ_{pk} the standard deviation of the capital price and σ_p the standard deviation of the output price.

Substituting (6) into (5), the two following properties can be derived: a positive correlation between the output and capital prices or an increase in the ratio σ_p/σ_{pk} would rise private investment. Simple examples may illustrate how these two effects work. Suppose that the output price increases. If firms are risk averse, then they will attempt to minimize the fluctuations of profitability. In such case, how should the capital price vary to enhance private investment? Because a change in output and capital prices have opposite effects on profitability, the capital price should move in the same direction as the output price; i.e. higher is the positive correlation between these two prices, lower will be the profitability fluctuations. Similarly, an increase in the ratio σ_p/σ_{pk} will affect positively private investment because if uncertainty concerning the change in the price of capital is greater than uncertainty concerning the change in the output price, then, other things being equal, the optimal portfolio --minimizing the profit fluctuations-- will have less movement in private investment than output. One major implication of this property is that an increase in the uncertainty concerning the output price (in relative terms) may lead to a higher adjustment in the capital stock than in production. The positive impact of an increase in the uncertainty of output price on private investment has been discussed by Abel [1983] and Hartman [1972]. These authors found that an increase in σ_p will lead to an increase in the optimal rate of investment because the risk about the future price of output tends to increase expected future marginal revenue product and hence investment. However, such a positive relationships was related to the assumption that a firm can compensate a poor investment choice by adjusting other inputs once the output price has been observed.

Finally, equation (5) shows that as firms become more risk averse, the adjustment of the private capital stock would be lower. The parameter μ is determined by the tangency of the mean-variance efficient frontier with the firm's utility function. Consequently, if firms become more risk averse the parameter μ falls, and therefore private investment.

2. An Empirical Application : The Case of Chile

This section takes an empirical look at the analytical model developed in the above section. We focus on the broad implications of the model by examining the relationships between private investment and the four following variables: (i) output level (Y), (ii) the price of capital (p_k), (iii) the ratio between the volatility of the price of capital and the volatility of the price of output (σ^2_p/σ^2_{pk}), and (iv) the correlation between the price of output and the price of capital ($\tau_{p,pk}$). A semi-log specification of these relationships would be:

$$(7) \qquad \ln(I_p) = \beta_0 + \beta_1 \ln(Y) + \beta_2 p_k + \beta_3(\sigma^2_p/\sigma^2_{pk}) + \beta_4 \tau_{p,pk}$$

with $\beta_1, \beta_3, \beta_4 > 0$ and $\beta_2 < 0$

The model is applied to the case of Chile over the 1980-90 period. This country has earned the reputation of being the "success" story of structural adjustment and has achieved fairly stable growth in the past eight years. Inflation has also been brought down to between 17 and 27 percent during this period. Despite these achievements, private investment in Chile has been slow to regain the levels reached prior to the 1982-83 crisis. There exist several empirical studies which have attempted to explain private investment behavior in Chile[5/]1. According to Serven and Solimano (1989, 1991), the stability and predictability of the incentive structure and the macroeconomic policy environment is the most important factor in explaining the evolution of private investment in Chile. The basic empirical result is that an increase in uncertainty --measured as the volatility of output, of prices, of the real exchange rate, of exports revenues-- would automatically decrease private investment.

The Data has been obtained from the Central Bank of Chile, the IMF's IFS and the World Bank [6/]. Private investment has been defined as real private investment (I_p) and output as real GDP (Y). We defined the price of capital (p_k) as the percentage change in the

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5/ See for example : Solimano [1989], Serven [1990], or Marshall and Schmidt-Hebbel [1991. In addition, Chile has been included in numerous cross-countries studies.

6/ We are grateful to A. Solimano for providing us the private investment series on a quarterly basis.

investment deflator as it has been done in previous studies on private investment in Chile. Because the ratio of the risks associated with the price of capital and the price of output is not directly observable, two indicators have been alternatively used. First, the volatility of the price of capital and the price of output have been calculated using a six-month moving average of the variance of the monthly percentage change in the investment deflator and in the consumer price index (σ^2_p/σ^2_{pk}). Second, we used the inflation rate measured by the GDP deflator for the volatility of the output price and the inflation rate measured by the investment deflator for the volatility of the capital price (p/p_k). Finally, the correlation between the price of output and the price of capital has been measured as the covariance between both prices ($\tau_{p,pk}$). The covariance has been calculated by using a six-month moving average of the GDP and investment deflators.

Table 1 reports the estimated results for Chile for the 1980-90 period using quarterly data. We used the TSLS technique because GDP and private investment are likely to be jointly determined and the AR(1) method has been used to correct the first-order autocorrelation of residuals in some regressions. Overall, the estimated results are quite satisfactory and the specification of the model is acceptable as suggested by the explanatory power of the regression (AdjR^2). More important, all estimated coefficients correspond to the ones predicted by the analytical model.

The most interesting aspect of the results concerns the effect of the uncertainty on private investment. Indeed, private investors appear quite sensitive to changes in the relative risk concerning the price of output and the price of capital. The positive and significant coefficient associated with the ratio (σ^2_p/σ^2_{pk}) suggests that lower was the volatility of the price of capital with respect to the volatility of price of output, higher was private investment. This result has been obtained with both measures of this relative risk since the impact of a change in the ratio p/p_k is also positive and statistically significant. We obtained a positive but not significant relationship between the covariance of capital and output prices and private investment. The impact of a change in GDP on private investment behavior appears to be high and significant and the response of private investment to a change in the price of capital was negative but (not always) significant. Finally, the dummy variable (dum1) which takes the value one in the first quarter of 1982 is statistically significant as found previously by Solimano [1989].

In order to compare the magnitude of the effects associated with the explanatory variables on private investment, **Table 2** summarizes the results in terms of elasticities and the mean and the standard deviation of the explanatory variables. At first glance, private investment appears relatively inelastic to changes in the price of capital and in sources of uncertainty. But, large variations, as high as 150 percent, in the price of capital or in the volatility of this price were quite common over the 1980-90 period, and in particular during the 1982-85 years. Interestingly, the above results suggest that the impact of uncertainty on private investment may be as important as the impact of a change in the price of capital and that such impact might be different according to the source of uncertainty.[7/] The model also illustrates that different sources of uncertainty may influence private investment in opposite directions. Indeed, the impact of a change in the output or the capital prices will affect private investment in opposite directions. Finally, the impact of a change in the correlation between the price of output and the price of capital on private investment appears relatively weak, but this explanatory variable was extremely volatile during the last decade.

3. Concluding Remarks

Understanding the roles of prices and quantities in investment demand is important for the analysis of adjustment policies in many developing countries. The recent literature on private investment emphasizes the role of uncertainty. The response of private investors to an increase in uncertainty is clearly negative, since the price of capital increases as a result of a higher risk premium -- the price to wait. Using the volatility of the price of capital as an indicator, this result has been confirmed by many empirical studies. This new development has been used to challenge one of the most popular policy recommendations derived from the traditional literature on investment: increasing investment by reducing the cost of capital through tax incentives or exchange rate policies. Because such policies are likely to increase the uncertainty concerning the price of capital, their effect on private investment is rather ambiguous. The intuitive idea is that private investors care more about the uncertainty concerning the price of capital than its existing level or even the expected one. In other words, incentives would have to be unreasonably high to bolster investors.

7/ To illustrate the relative importance of uncertainty on the private investment behavior in Chile, let us take a numerical example. A 100 percent reduction in the ratio (σ^2_p/σ^2_{pk}) would decrease the level of private investment by about 2.2 percent. A 55 percent reduction in the price of capital would be required to offset the first negative impact.

However, the efficiency of policies aimed to enhance private investment depends on the environment in which these changes occur, thereby affecting the link between uncertainty and private investment. We argue that the uncertainty concerning the cost of capital should be compared with uncertainty in the price of output. If the volatility of the output price is greater than the volatility of the cost of capital, the optimal choice of the firms will contain less movements in production than in capital because investors are risk-averse who minimize profit fluctuations. For the same reason, a positive correlation between changes in the output and capital prices is likely to enhance private investment.

Although the model can be improved in many ways -e.g. the production level is likely to be influenced by uncertainty as well- the major policy conclusions that can be drawn from the exercise are straightforward. Policies aiming to reduce the price of capital will increase the volatility of this price, at least in the short-run. This can negatively affect private investment and decrease the probability of success of the reforms. When a policy reform is introduced, it is almost inevitable that the private sector will view it as less than one hundred percent sustainable. Nevertheless, the model developed in this paper suggests the efficiency of these policies may be enhanced (i) *if the volatility of the output price is greater than the volatility of the cost of capital*, and (ii) *there is a positive correlation between changes in the output and capital prices*. In both cases, private investment will be more responsive to changes in the price of capital (or in aggregate demand) because firms will minimize profit fluctuations.

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Table 1: Estimates
Log of Private Investment in Chile (1980.1-1990.4)
(t-statistics in parenthesis)

	Constant	ln(Y)	p_k	$\sigma^2_\pi/\sigma^2_{\pi k}$	p/p_k	$Cov_{\pi,\pi k}$	Dum1	$AdjR^2$	DW
$\ln(I_p)$	-7.715	2.192	$-0.15\ 10^{-3}$		0.035	$0.11\ 10^{-4}$		0.839	2.48
	(-3.35)	(4.34)	(-1.68)		(1.78)	(1.95)			
$\ln(I_p)$	-7.233	2.082	$-0.14\ 10^{-3}$		0.0612	$0.5\ 10^{-4}$	0.458	0.878	2.35
	(-3.26)	(4.29)	(-0.66)		(2.36)	(1.55)	(3.57)		
$\ln(I_p)$	-9.643	2.614	$-0.19\ 10^{-3}$	0.052		$0.6\ 10^{-5}$		0.866	2.28
	(-3.09)	(4.82)	(-1.00)	(1.87)		(1.43)			
$\ln(I_p)$	-9.333	2.547	$-0.18\ 10^{-3}$	0.063		$0.4\ 10^{-5}$	0.379	0.846	2.57
	(-4.91)	(6.12)	(-0.90)	(1.96)		(1.83)	(2.76)		

Table 2: Chile (1980:II-1990:IV)
Elasticities of Private Investment

Variables	Average Elasticities a/	Mean	Standard Deviation
GDP	2.64	97.06	12.93
p_k	-0.04	20.82	24.38
σ^2_p/σ^2_{pk}	0.0218	0.42	0.61
$\tau_{p,pk}$	$0.3\ 10^{-5}$	0.42	21.25
σ^2_p	0.005	7.55	7.643
σ^2_{pk}	$-0.4\ 10^{-3}$	86.48	132.20

a/ Average elasticities on the 1980-90 period.

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